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PHYS 230 HW 1

CQ1. Imagine holding two objects, a balloon and a rock, under water. Each object is precisely equal in size.

a) How do the buoyant forces, exerted on each of these two objects, compare?

b) How do the buoyant forces compare when the balloon becomes deflated to half of its original size?

c) Now both objects of equal size are released from rest under water. Which object floats and which object sinks? Why is this the case?

a.) The buoyant force on the balloon is the same as the rock. Buoyant force is depent on fluid density, volume, and gravity. These are all the same.

$F_B = \rho_f V_f g$

$B_b = B_R$

b.) When half of the volume decreases in the balloon it becomes half as strong as the rocks buoyant force.

$B_b = \frac{1}{2} B_R$

c.) The balloon will float due to its buoyant force baloneing out its weight. The rock will sink due to it being more dense and weighing more.

Balloon Floats
Rock Sinks

CQ2. Water and oil do not mix and will stay separated when gently combined within a container; it is noted that the density of oil is smaller than the density of water. Imagine water being poured into a U-shaped tube that is open at both ends until the water surface is halfway up each leg of the tube. Oil is then poured on top of the water in the right leg only. Allowing the system to come to equilibrium, are the top of the oil column in the right leg and the top of the water in the left leg at the same height? If not, which is higher?

oil side is higher

The oil side is higher due to it needing to be higher in order for the pressures of the two sides to be equal so it can be in hydrostatic equilibrium.

CQ3. While driving your car, the passenger in the front seat lights a cigarette and opens the window slightly. Why is it that the smoke blow out of the car? Why doesn't some of the air from the outside flow into the car instead?

The car is pressurized

This is because the car is pressurised so the air from it is pushing outward when the window is cracked. There is a net force on the window outward due to it.

P1. Consider your text book lying on a rock at sea level with the front cover facing up. Your text is 7.0 mm thick, 21 cm wide, and 27 cm long with a mass of 320 g.

a) What is the average density of your favorite text book?

b) How does the force exerted by atmospheric pressure on the front cover compare with the force of gravity on the book? Express the answer as a ratio.

a.) $\rho = m/v$ $\quad$ $V = H \cdot W \cdot L$

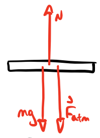
$m = 0.320\ kg$ $\quad$ $V = 0.007m \times 0.21m \times 0.27m$

$V = 3.969 \times 10^{-4} m^3$

$\rho = m/v: \frac{0.320\ kg}{3.969 \times 10^{-4} m^3} = 806.248\ kg/m^3$

$\rho = 806\ kg/m^3$ $\quad$ $806.25\ kg/m^3$ $\quad$ $\rho = 810\ kg/m^3$

b.)



$F_{air} = PA$ $\quad$ $P = 101{,}300\ PA$

$F_g = mg$ $\quad$ $A = L \times W$

$A = LW$
$= (0.27m)(0.21m)$
$A = 0.0567 m^2$

$F_{air}: F = (101{,}300 Pa)(0.0567 m^2)$
$F_A = 5{,}743.71 N$

$F_G: F = mg$
$= (0.320 kg)(9.8 m/s^2)$
$F_G = 3.136 N$

1800

$\frac{F_A}{F_G} = \frac{5{,}743.71N}{3.136N} = 1831.54$ $\quad$ $F_A : F_G$

1831.54 $\quad$ $\frac{1832\ F_{Patm}}{1\ F_{mg}}$

P2. The earth has a mass of $M_E = 5.97 \times 10^{24}$ kg and a radius of $R_E = 6.38 \times 10^6$ m. Approximating the earth as a perfect sphere, calculate the average density of earth.

$\rho = M/V$ $\quad$ $V: V = \frac{4}{3}\pi r^3$ $\quad$ $V = \frac{4}{3}\pi(6.38 \times 10^6 m)^3$

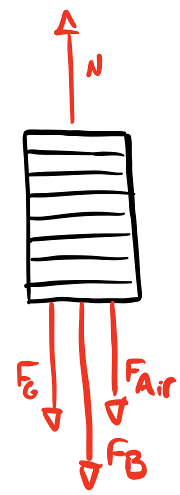
$r = 6.38 \times 10^6 m$ $\quad$ $V = 1.088 \times 10^{21} m^3$

$M = 5.97 \times 10^{24} kg$
$V = \frac{4}{3}\pi r^3$

$\rho: \rho = \frac{5.97 \times 10^{24} kg}{1.088 \times 10^{21} m^3} = 5488.12\ kg/m^3$

$\rho = 5.49 \times 10^3\ kg/m^3$ $\quad$ $5488.12\ kg/m$

P3. Boards used in building construction can typically withstand a pressure of 1.4×10^7 Pa before being crushed. Assume that the mass density of these boards is 960 kg/m^3. Calculate the height, h, that these boards can be stacked before the boards at the bottom of the pile are crushed. Assume that these boards are all identical and are stacked precisely on top of one another.



$\rho = M/V$
$P = F/A$
$F = mg$

$P = mg/A$
$AP = mg$
$m = \frac{AP}{g}$

$\rho = \frac{AP/g}{V}$

$\rho = \frac{AP}{Vg} = \frac{\cancel{lw}P}{\cancel{lw}hg} = \frac{P}{hg}$

$\rho hg = P$

$h = \frac{P}{\rho g} = \frac{1.4 \times 10^7 \frac{kg}{ms^2}}{960 \frac{kg}{m^3}(9.8 m/s^2)}$

$Pa = \frac{kg}{m \cdot s^2}$

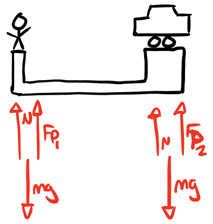
$P = 1.4 \times 10^7 Pa$
$\rho = 960\ kg/m^3$
$a = 9.8 m/s^2$

$h = 1.49 \times 10^3 m$ $\quad$ $h = 1488.1\ m$ $\quad$ 1500m

$P_{max} = P_{atm} - \rho gh$

$h = \frac{P_{max} - P_{atm}}{\rho g} = \frac{1.4 \times 10^7 Pa - 1.01 \times 10^5 Pa}{960 kg/m^3 (9.8 m/s^2)} = 1477.36m$ $\quad$ $h = 1.48 \times 10^3 m$

P4. Consider a hydraulic lift where you are standing on the left piston and a car is sitting on the right piston. The pistons are at the same height above the ground and neither you nor the car is moving. The piston on the right has a radius of 1.5 m. If the car has a mass of 1200 kg and you have a mass of 65 kg, calculate the radius of the left piston.



$m_p = 65$ kg
$m_c = 1200$ kg

$F_{P_1} = F_{P_2}$ — same depth

$\cancel{P_0} + \frac{m_1 \cancel{g}}{A} = \cancel{P_0} + \frac{m_2 \cancel{g}}{A}$

$\frac{m_1}{\pi r_1^2} = \frac{m_2}{\pi r_2^2}$

$\frac{1}{r_1^2} = \frac{\cancel{\pi} m_2}{\cancel{\pi} m_1 r_2^2}$

$\frac{1}{r_1^2} = \frac{m_2}{m_1 r_2^2}$

$M = \rho V$
$M = \rho A d$
$\rho = \frac{m}{Ad}$

$r_1^2 = \frac{m_1 r_2^2}{m_2}$ $\quad m_1 = 65$ kg, $m_2 = 1200$ kg, $r_2 = 1.5$ m

$r_1 = \sqrt{\frac{m_1 r_2^2}{m_2}}$

$r_1 = \sqrt{\frac{65\text{kg}(1.5\text{m})^2}{1200\text{ kg}}}$

$r_1 = 0.35$ m

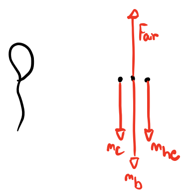
$r_L = 0.35$ m

P5. You wish to calculate the lifting force of a helium balloon. You tie a long cord to the balloon before releasing it and find that the balloon floats upward until it supports 8.46 cm of cord, where it then comes to equilibrium and hovers at a fixed height. A 100.-m length of the cord has a mass of 1.85 kg and the mass of the balloon, void of helium, is 4.55 g. The mass densities of air and helium are 1.29 kg/m^3 and 0.179 kg/m^3, respectively.

a) Construct the free-body diagram for the balloon with a labeled force vector for each individual force acting on the balloon.

b) Calculate the volume of the inflated balloon?

a.)



b.)

$F_B = F_{m_c} + F_{m_b} + F_{m_{he}}$

$\rho_f V_f g = m_c g + m_b g + m_{he} g$

$\rho_f V g = m_c g + m_b g + \rho_{he} V g$

$\rho_f V g - \rho_{he} V g = m_c g + m_b g$

$V(\rho_f g - \rho_{he} g) = m_c g + m_b g$

$V = \frac{m_c g + m_b g}{\rho_f g - \rho_{he} g}$

$V = \frac{m_c + m_b}{\rho_{O_2} - \rho_{He}}$

$V = \frac{1.57\times10^{-3}\text{kg} + 4.55\times10^{-3}\text{kg}}{1.29\text{kg/m}^3 - 0.179\text{kg/m}^3}$

$V = 5.509\times10^{-3}\text{ m}^3$

$\rho = \frac{m}{V}$
$m_{he} = \rho_{he} V$

m_c: $\frac{1.85\text{ kg}}{100\text{m}} = \frac{x\text{kg}}{8.46\times10^{-2}\text{m}}$

$x = \frac{1.85\text{kg}(8.46\times10^{-2}\text{m})}{100\text{m}}$

$m_c = 1.57\times10^{-3}$ kg

$m_c = 1.57\times10^{-3}$ kg
$m_b = 4.55\times10^{-3}$ kg
$\rho_{O_2} = 1.29$ kg/m^3
$\rho_{He} = 0.179$ kg/m^3

$V = 5.51\times10^{-3}\text{ m}^3$